

Watersheds 101: Useful Things to Know About Your Water Resources

FOCUS

- Hydrologic Unit Codes
- Water Quality Monitoring
- Geographic Information Systems

A watershed is all of the landscape that drains into a particular lake or river. Depending on the scale of the discussion, you could refer to the watershed of the Mississippi River, or the watershed of a farm pond. There are hierarchies that use terms such as drainage basin and river basin to mean specific hydrologic configurations. However, you may hear them used interchangeably with “watershed.”

Hydrologic Unit Codes: the watershed address

Hydrologic unit codes were developed by the US Geological Survey (USGS) in cooperation with the US Water Resource Council. The USDA Natural Resources Conservation Service has incorporated this coding into its conservation planning practices. Most state agencies also use this coding system. The advantages are as follows:

- The hydrologic code attached to a specific watershed is unique.
- This code provides a common language for different organizations and agencies to use. If a code has been assigned, then there is agreement as to the boundaries of the watershed.
- Having watersheds delineated on published maps assists the public in understanding how landscapes function, where water quality problems may be addressed, and who needs to be involved in the planning process.

Example: An example of a fourteen-digit hydrologic unit code would be 05120201-010-001. Each number or group of numbers in the code represents a specific landscape area.

Region	Subregion	Accounting Region	Cataloging Unit	Cataloging Subunit	Subdivision of Subunit
05	12	02	01	010	001

Numbering of watersheds is consecutive from upstream to downstream. The first two digits indicate the main river basin. The third digit may indicate all or a portion of that basin. In this way the third digit can be changed to designate, for example, two parts of a watershed on either side of a state line. *The longer the HUC number, the smaller the watershed.*

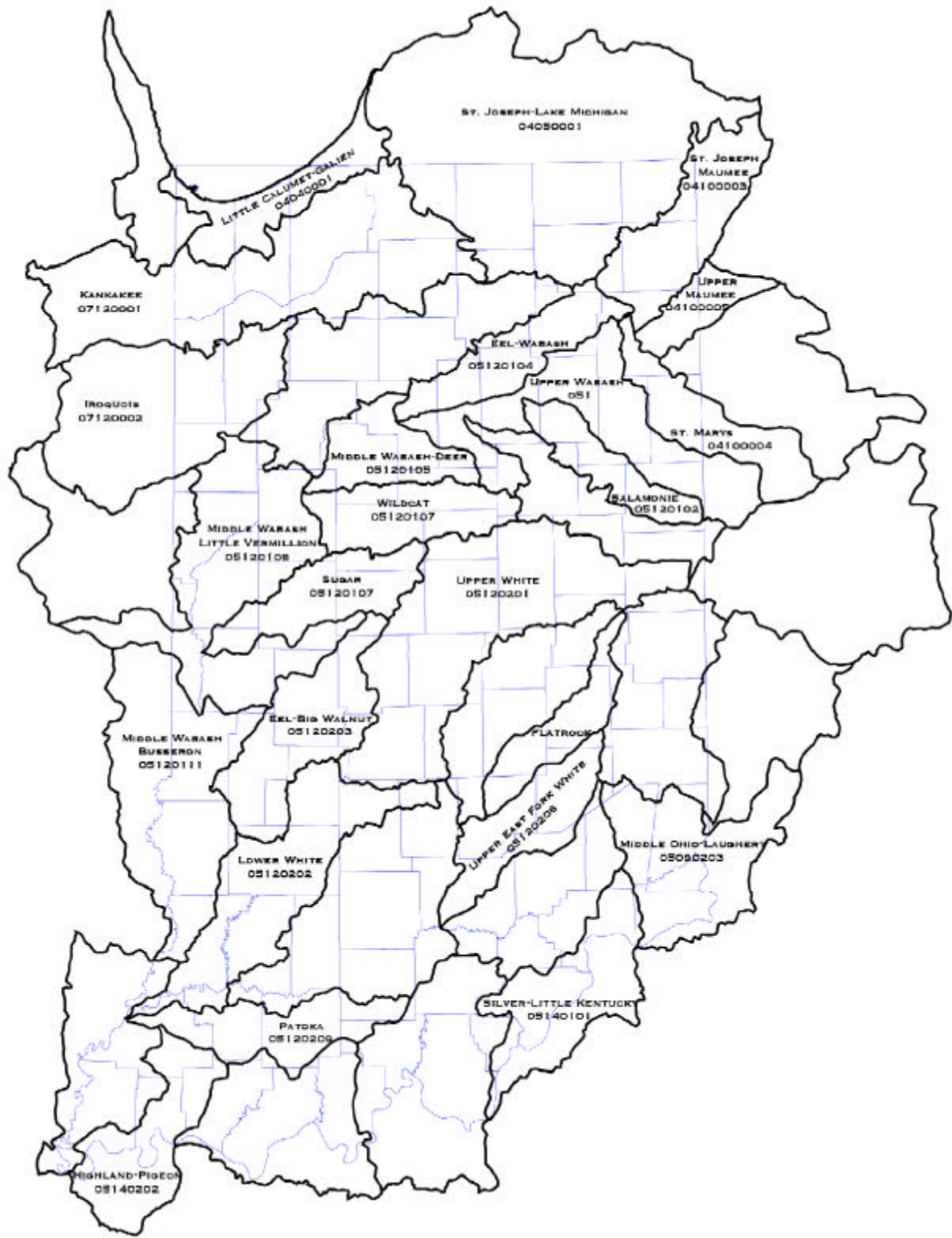
It is important to remember that **watersheds refer to surface water only**. Groundwater, which also is a drinking water source, is influenced by surface water but occurs in aquifers, not watersheds. The aquifers of Indiana have been mapped in the *Indiana Groundwater Atlas* (USGS). They have also been grouped in common hydrogeologic settings according to geology, vulnerability, et cetera (Maps & CD-ROM distributed by Office of the Indiana State Chemist). When addressing water quality issues, both ground and surface water should be considered.

Table 1 lists the Hydrologic Units in Indiana, along with the watershed names that have been assigned by the USGS.

For general information on your watershed, visit the U.S. Environmental Protection Agency internet site called *Surf Your Watershed* at www.epa.gov/surf/. Also check out IDEM's website at www.state.in.us/idem/owm for information on impaired waters.

The entire country has been mapped at the eight-digit hydrologic unit code level (about 2,211 watersheds). Indiana is divided into 39 eight-digit watersheds (see map, facing page). The U.S. Geological Survey, working with the Natural Resources Conservation Service, has further mapped Indiana's watersheds at the 14-digit level. These smaller watersheds average about 9,000 acres. The 14-digit maps are available from USGS and also on the USGS website.

8 Digit Watersheds

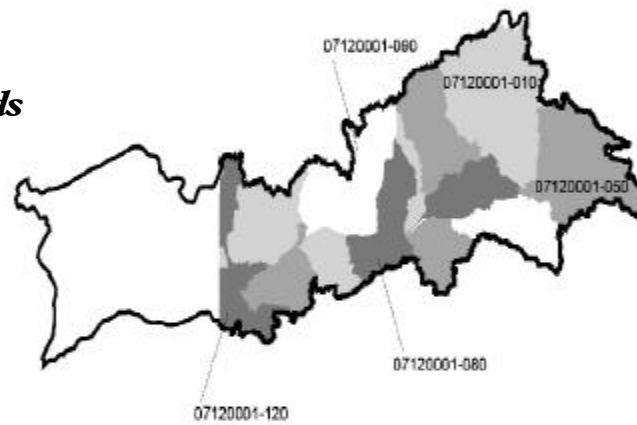


Source: IDEM, Office of Water Management, 1998

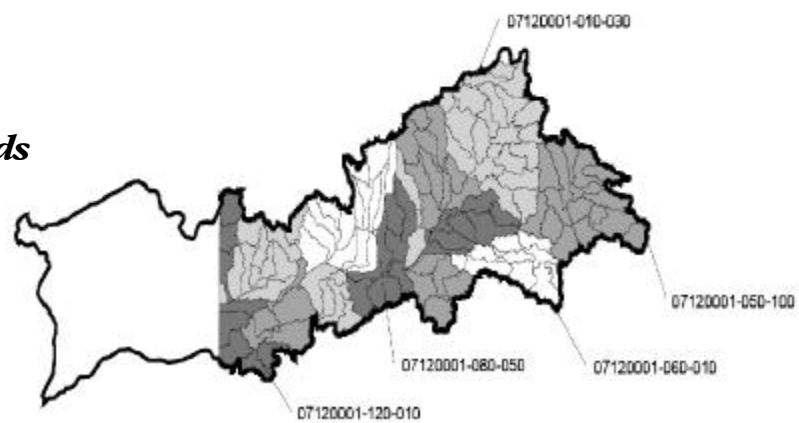
***8 Digit
Watershed***



***11 Digit
Watersheds***



***14 Digit
Watersheds***



Source: IDEM, Office of Water Management, 1998

Table 1. Hydrologic Unit Codes, Indiana, 8-digit

HUC	River	Counties
04040001	Little Calumet-Galien	Lake, Porter, LaPorte
04050001	St. Joseph	St Joseph, Elkhart, Lagrange, Stueben, Kosciusko, Noble, Dekalb
04100003	St. Joe	Steuben, Dekalb, Noble, Allen
04100004	St. Mary's	Allen, Wells, Adams
04100005	Upper Maumee	Allen, Dekalb
04100007	Auglaize	Allen, Adams
05080001	Upper Great Miami	Union, Franklin
05080003	Whitewater	Randolph, Wayne, Henry, Franklin, Fayette, Union, Rush, Decatur, Ripley, Dearborn
05090203	Middle Ohio-Laughery	Decatur, Franklin, Ripley, Dearborn, Switzerland
05120101	Upper Wabash	Grant, Howard, Miami, Cass, Adams, Wabash, Huntingtin, Whitley, Allen, Wells, Jay
05120102	Salamonie	Wabash, Huntington, Grant, Wells, Blackford, Jay
05120103	Mississinewa	Miami, Wabash, Grant, Madison, Blackford, Delaware, Jay, Randolph
05120104	Eel (Upper)	Noble, Whitley, Allen, Kosciusko, Wabash, Miami, Fulton, Cass
05120105	Middle Wabash-Deer	Cass, White, Carroll, Howard, Miami, Tippecanoe
05120106	Tippecanoe	Noble, Whitley, Kosciusko, Marshall, Fulton, Miami, Cass, Starke, Pulaski, Jasper, White, Carroll, Tippecanoe, Benton
05120107	Wildcat	Tippecanoe, Carroll, Clinton, Howard, Tipton, Grant, Madison
05120108	Middle Wabash-Little Vermillion	Benton, White, Warren, Tippecanoe, Fountain, Vermillion, Montgomery, Parke
05120109	Vermillion	Benton, Warren, Vermillion
05120109	Sugar	Fountain, Parke, Montgomery, Boone, Clinton

HUC	River	Counties
05120111	Middle Wabash-Busseron	Vermilion, Vigo, Clay, Sullivan, Greene, Knox
05120112	Embarras	Illinois, Border
05120113	Lower Wabash	Knox, Gibson, Vanderburgh, Posey
05120201	Upper White	Owen, Morgan, Johnson, Hendricks, Marion, Hancock, Boone, Hamilton, Tipton, Madison, Delaware, Randolph, Henry
05120202	Lower White	Gibson, Knox, Pike, Daviess, Sullivan, Greene, Martin, Owen, Monroe, Brown
05120203	Eel (Lower)	Greene, Owen, Vigo, Clay, Putnam, Morgan, Hendricks, Boone
05120204	Driftwood	Bartholomew, Brown, Johnson, Shelby, Marion, Hancock, Rush, Madison, Henry
05120205	Flatrock-Haw	Bartholomew, Shelby, Rush, Decatur, Fayette, Henry
05120206	Upper East White Fork	Jackson, Brown, Bartholomew, Jennings, Decatur, Shelby, Rush
05120207	Muscatatuck	Washington, Jackson, Scott, Clark, Jennings, Jefferson, Ripley, Decatur
05120208	Lower East White Fork	Pike, Daviess, Dubois, Martin, Orange, Greene, Lawrence, Washington, Monroe, Brown, Jackson, Bartholomew
05120209	Patoka	Gibson, Pike, Dubois, Spencer, Perry, Crawford
05140101	Silver-Little Kentucky	Harrison, Flyod, Clark, Scott, Jefferson, Ripley, Switzerland
05140104	Blue-Sinking	Perry, Crawford, Harrison, Floyd, Orange, Washington
05140104	Lower Ohio- Little Pigeon	Vanderburgh, Warrick, Pike, Dubois, Spencer, Perry, Crawford
05140202	Highland Pigeon	Posey, Vanderburgh, Warrick, Gibson
07120001	Kankakee	Lake, Newton, Porter, Jasper, Laporte, Starke, Pulaski, St Joseph, Marshall, Elkhart, Kosciusko
07120002	Iroquois	Lake, Newton, Jasper, Pulaski, White, Benton
04060200	Lake Michigan	----

Geographic Information Systems (GIS)

What is a GIS? A geographic information system is a computer-based tool for mapping and analyzing things that exist and events that occur. GIS technology integrates common database operations such as statistical analysis and queries with the unique visual benefits offered by maps. A GIS works by storing information about the world as a collection of thematic layers that can be linked together by geography. Each bit of information contains either a geographic reference such as latitude and longitude, or an implied reference such as an address, zip code, census tract, or road name. These references allow you to locate features such as forest stands, and events such as earthquakes, on the earth's surface.

Vector & Raster. GIS works with two fundamentally different types of geographic models, the “vector model” and the “raster model.” In vector, information is stored as a series of x/y coordinates or points. The location of a point feature such as a gas well can be described by a single set of coordinates; a river would be a collection of points. Areas such as watersheds or sales territories can be stored as a closed loop of coordinates. This method is useful for mapping discrete features but is not much use for continuously varying features such as soil type. The raster model is made up of a collection of cells in a grid, like a scanned picture made up of pixels or a paint-by-number picture. A GIS system can handle both models.

What does a GIS do?

Input: data has to be converted into a digital format before being used in a GIS, so the system “knows” where everything is. Many types of data already exist in GIS-compatible formats, and can be loaded directly into a system. Other data has to be digitized, which may be time-consuming.

Manipulation: Data types need to be manipulated to be compatible, for instance, so that they are all at the same map scale and can be layered on top of each other (roads, rivers, and population on a base map of land use, for example.) Manipulation tools are built into currently available systems.

Data Management: For small projects, data may simply be stored as files. For large projects, a database management system is needed.

What can you do with a GIS?

Ask questions! In fact, learning to frame your questions correctly is key to getting the most from a GIS. You can ask simple questions like, “Where do the people live and work in my watershed?” or complex analytical questions like, “If we build a new highway here, how will the community be affected?” Two important tools of a GIS are proximity analysis (How many houses are within 500 feet of this stream and where are they?) and overlay analysis (Show me all the soils, slope, vegetation, and land ownership). Most GIS reports are maps, sometimes with tables attached.

Related technology: GPS, or global positioning systems, measure specific locations on the earth's surface using satellite signals and are available as hand-held units. The signals can be transposed into map positions in the GIS. GPS units are commonly used for surveying, navigation, and locating features such as dams, pipe outfalls, et cetera.

What GIS is NOT: GIS is not a decision-making system. It is a tool that supplies information in a form that may make it easier for a group to arrive at decisions, but it can also be confusing if the questions are not framed well. It is also only as good as the information that is fed into it! GIS is also not absolutely

essential to watershed planning. A great deal of information can be presented on ordinary paper maps and transparent overlays for much less than the cost of a GIS system and the training required to operate one. It is a wonderful tool if the money and manpower are available. Consider partnering with another group, agency, local government, or university to gain access to a GIS for your watershed planning process.

Commonly available GIS products: ArcView is available from ESRI (a commercial company). It allows viewing of spatial data, compiling of layers into maps, primarily used with readily available databases.

ArcInfo is available from ESRI. It allows complex data analysis, suited to manipulating large volumes of data.

For more information, check out your local community college and the library, look at ESRI's website, and talk to county planning officials. If they do not presently have a GIS, they probably have researched purchasing one and have recent information.

A short course on water & water quality monitoring

This section is courtesy of Dr. Gwen White, IDNR

Volunteer water quality monitoring provides many cost-effective benefits to the participants and the watershed community. Volunteers who are trained in monitoring are well prepared to educate themselves and local communities about the connection between their actions and the future quality of life in the watersheds. Adults and students in school classes or clubs can acquire the interdisciplinary skills in chemistry, biology, physics, and public policy that are required for making effective decisions regarding resource management.

Brief history of water quality monitoring

Public policy balances short-term individual benefits against quality of life for neighbors and future generations. The national water quality goals first articulated in the Clean Water Act in 1972 include "fishable and swimmable" waters; elimination of polluting discharges; and protection of public water supplies, aquatic life, and recreational activities. The term "fishable and swimmable" indicates a goal of maintaining or restoring potential water uses and reflects a long European history of recognizing the rights of the public to have resources available to fish, hunt, and use water for drinking and crops. Monitoring is mandated at the state agency level by the Clean Water Act, which requires all states to report to Congress every two years on progress toward water quality goals.

Since the Clean Water Act was enacted in 1972, the understanding of water pollution sources and focus of water quality monitoring has expanded. The original act reflected the urgency of dealing with severe problems caused by point-source pollution, including discharges from industries, sewage treatment plants, and other commercial facilities. The exact source was relatively easy to identify and measure as a discharge from "the end of a pipe." The first substantial case regarding water quality issues and the Endangered Species Act occurred in 1978 when the Supreme Court halted construction on the Tellico Dam because the dam would threaten an endangered species of fish known as the snail darter. Less than 10 years later, the Clean Water Act was amended to address non-point sources of pollution through Section 319, which requires states to identify water bodies where control of nonpoint source pollutants is necessary to meet

water quality standards and to establish management programs for listed waters. Funding from the US Environmental Protection Agency is channeled through the Indiana Department of Environmental Management (IDEM) to address issues related to Section 319. *Projects receiving funding through this program are required to have a monitoring component.*

The most recent shift in water quality issues has been the recognition that habitat changes impair water quality as much or more than direct chemical and physical changes. The original Clean Water Act included provisions to address discharge of dredged or fill material in “waters of the United States” in Section 404. However, the extent of this jurisdiction was not clear until 1985 when the Supreme Court concluded that the Army Corps of Engineers had broad jurisdiction over any area flooded or saturated enough to support wetland plant and animal life. A number of uses either were exempted from jurisdiction or covered under broad general permits. Continued discussion of these actions has resulted in a debate regarding private property rights and public benefits.

Monitoring land-use effects on water quality has paralleled the shifting focus on problems reflected in the law. Most monitoring initially was conducted around point sources of pollution and measured chemical and physical characteristics. During the 1980s, several scientists recognized developed methods for using plant and animal communities to indicate the water quality for human use and to sustain ecosystems. W. L. Hilsenhoff developed one of the first systematic methods for use with aquatic macroinvertebrates (e.g., insects, leeches, snails) in 1982. James Karr developed a method for fish in 1986. Building on these methods, state agencies, including IDEM, have begun monitoring the quality of aquatic plant and animal communities, as well as conducting habitat assessments, in watersheds across Indiana. However, as of 1998, state water quality standards have not been set for the quality of habitat or plant and animal communities.

Volunteer monitoring can . . .

... expand information available through state monitoring programs.

The more data available to a watershed group, the better the group will understand and prioritize problems and potential solutions. States are required to submit regular reports to Congress on water quality. These are called “305(b)” reports in reference to the section of the Clean Water Act that provides the requirement. However, due to several limiting factors, information may not be available from state or federal agencies at locations in the watershed that are critical to project success. Physical or political access to some sites on private land may be limited to state agency personnel. Volunteers working in a watershed can obtain data for discrete use at the local level. Volunteers should always acquire permission from adjacent landowners prior to collecting information.

... stretch funding for watershed monitoring.

State-funded projects will include limited monitoring at the beginning and ending of projects. Collecting information on baseline and long-term trends in water quality can be expensive and time consuming, but it is essential for making appropriate decisions about watershed management. Limitations in funding may reduce the number of samples over space and time. Repeated monitoring can be used to distinguish between natural variability and changes caused by humans.

Consultant fees for monitoring can consume a significant proportion of project funding. Volunteer data will give supplemental information in years when funding for professional monitoring is not available. Volunteers increase the amount of information that can be collected with limited funding and target further professional monitoring to the most cost-effective areas. By matching volunteer monitoring with professional

monitoring at the same or nearby sampling sites, data from volunteers can be confirmed by professional monitoring. Results of the additional sampling by volunteers can be compared to periodic professional monitoring for calibration and validation.

... provide data needed to identify and prioritize need for restoration in the watershed.

Many state and federal programs depend on local groups to request funding for projects that would improve water quality. Local agencies and volunteers can identify the need for projects by acquiring information on the current status of local waters. Effective watershed management depends on identifying the sources of problems and the success of implemented solutions. Volunteer monitoring can provide information on project success that may be needed for continued support and to determine when existing methods are no longer functional or appropriate under a watershed's particular conditions.

... provide important information in determining impacts of catastrophic events.

Volunteers usually know their watershed history better than nonresidents and can reach locations for sampling more quickly after a significant event, such as a heavy rain or a chemical spill. Physical evidence of accidental spills may pass quickly without attention from agency officials. Sources of non-point pollution often are not obvious from maps or other resources available to off-site consultants. Watershed residents often have specialized knowledge of potential problem areas.

... provide appropriate information for decision making in a watershed.

The accuracy and utility of volunteer data for making decisions about land-use management has been proven in many established state programs. The National Weather Service was the first agency to successfully train volunteers to collect valid data. Recent studies in several states with established volunteer monitoring programs indicate that volunteers and agency biologists detected similar general patterns of water quality. Volunteer biases were fairly standard and could be improved with additional training. Volunteers tended to err by indicating greater pollution in clean streams and less pollution in stressed streams. The biases were corrected by emphasizing training in recognizing cryptic (small), rare, or indicator species. Most methods of measuring water quality using a scoring system account for natural variability over space and time and indirect influences of human land use. Therefore, carefully trained volunteers can provide information at the appropriate scale needed to make decisions regarding land use. Volunteer monitoring was most effective when used as an "early warning" system that is followed by agency biologists where needed. The single most important factor in effective monitoring is good record keeping.

The Importance of Test Parameters

The **habitat** of the stream determines many aspects of the stream or lake structure and affects some chemical characteristics. Vegetation along the bank filters nutrients and sediment in runoff. Trees and large shrubs at the waterline shade the stream, lowering the temperature and reducing algae growth. Tree roots, fallen logs and large boulders in shallow areas provide cover and nesting sites for fish and other animals. Many insects and sport fish species in Indiana streams require clean sand or gravel for and nesting sites. Species diversity is usually lower and exotic species, such as carp, often dominate where water is muddy and banks are eroding.

Physical characteristics of water include temperature, turbidity, and velocity. Like humans, plants

and animals are adapted to a particular range of temperature. In a hot environment, body processes speed up and organisms need more food and fluids, and use more energy to regulate body temperature, leaving less energy for other important activities like finding food or shelter. In a cold environment, body processes and behavioral activities slow down. Animals will move to a part of the water where temperature is more comfortable (e.g., shaded or deeper cold water in summer). Cold water has space for oxygen because molecules move more slowly. Warm water drives out oxygen. The toxic effects of some chemicals increase as water heats.

Sedimentation can cause a cascade of negative effects in water. Soil increases water temperature by absorbing heat. Poor water clarity interferes with feeding in predators that hunt by sight (including many sport fish), can cause hybridization if species that select mates by sight (e.g., sunfish), clogs gills during breathing and feeding, smothers nests and eggs, and fills crevices in gravel beds. Soil can carry attached toxic chemicals and phosphorus into the water. Erosion can carry dead plant and animal matter into water, which increases the fertilizing effect and burns oxygen through decomposition. Insects and other small organisms that thrive on breaking down plant matter increase at the expense of other organisms.

Velocity and discharge describe the amount and speed of water in the stream. Plants and taller algae forms rarely grow in fast-moving water due to damage from the force of the water. Only streamlined animals or animals with appendages for clinging to rocks or sticks live in fast-moving water. Energy spent in maintaining position in fast currents is not available for other important functions such as feeding or reproducing. In general, fast-moving or turbulent water contains more oxygen and is more well-mixed chemically, with an even temperature, than slower or ponded water that may have warm and cool spots, less oxygen, and areas with higher and lower pollution levels.

The **pH** of the water affects and responds to chemical reactions in the water. The pH measures relative amounts of acids and bases in water. The pH in Indiana waters generally averages from 7 to 9. When algae or plants consume carbon dioxide and produce oxygen, a chemical reaction causes the pH to increase up to 10. Decay of plant or animal matter also can cause the pH to decrease down to 6. Most Indiana waters are naturally hard with a large capacity to buffer changes in the pH. There are some waters affected by acidic mine drainage in which the pH is a potential problem for life in the water.

Oxygen is critical to sustain life for most organisms, including plants and animals. Plants produce oxygen during the day but consume oxygen at night or in cloudy conditions. Low oxygen can cause degradation or death by disrupting development or killing eggs and embryos; increasing toxicity of some chemicals; and reducing energy available to find food, fight disease, and reproduce. Animals that live or nest in shallow water are particularly susceptible to rapid changes in the amount of oxygen in water due to heating or decomposition.

Nutrients, or fertilizers, include any chemical that is required to increase the growth of plant or animal communities. Many of these chemicals are generally abundant enough to support populations. However, the key to managing plant or animal growth is to identify the nutrient that is required for growth and is in short supply (limiting factor). On land, most plant populations are largely limited by the availability of nitrogen. In water, most plant populations are limited by phosphorus. Additionally, sources of phosphorus are more easily controlled than sources of nitrogen. Plants or microscopic organisms that remove nitrogen from the air and convert it for use by other plants are often abundant. Phosphorus originally comes from rocks and is recycled in living systems by the process of consumption and decay.

Phosphorus is not directly toxic to plants or animals, but can kill fish or other oxygen-breathing animals through the indirect effect of increasing plant populations. Plants produce oxygen during the day and consume oxygen at night. An overabundance of plants causes so much oxygen in water that gas bubbles are

often seen on plant stems and leaves on sunny days (supersaturation). The large plant or algae population consumes an equally large amount of oxygen at night and can drive oxygen levels to nothing. This effect commonly causes fish or frog kills.

Nitrogen occurs in water in four different chemical forms: organic, or TKN; nitrate; nitrite; and ammonia. **Ammonia** is found in surface and waste waters but is usually low in groundwater because it attaches to soil. Ammonia can be toxic to fish, especially at high pH and high temperature. Ammonia decomposes into nitrate. **Nitrate** usually is low in surface waters but may be high in groundwater or tile drainage. Nitrate can cause sickness and death of unborn or infant humans and animals through an effect commonly known as “blue baby syndrome.” Nitrate can interfere with the ability of iron to carry oxygen in blood, causing the young animal to chemically suffocate. The national standard for nitrate is set at 10mg/l to prevent this effect. Nitrite is highly toxic but usually is found in small amounts and rapidly converted into other forms. Nitrite can enter a water supply through industrial discharges. If nitrite is measured at all, the combination of nitrate and nitrite are generally measured together. Organic nitrogen represents a combination of most forms of nitrogen that are carbon-based molecules and byproducts of plant or animal decay, including proteins, urea, and numerous synthetic materials. Measurement of organic nitrogen is often called “TKN” or total kjeldahl nitrogen, after the technique used in the test.

There are many natural and human sources of nutrients in water. Human sewage can enter from treatment plants and septic systems. Livestock waste can enter from overflowing manure pits or runoff following land application on fields. Wild animals and pets are also a source of nutrients. Eroding soil can carry phosphorus and ammonia. Drain tiles carry nitrates dissolved in water. Decay of organic matter from leaves, grass clippings, wood, dead plants and animals, and landfills can contribute organic nitrogen and phosphorus. Chemical tests cannot distinguish the source of nutrients but can indicate the amount of nutrients relative to the location of known sources of nutrients.

Wastewater presents a threat of spreading water-borne diseases. Many **pathogenic (disease-causing) organisms** are small, difficult to sample and identify, and dangerous to maintain for testing in the laboratory. Coliforms and fecal streptococci are two groups of bacteria found in the waste of warm-blooded animals. As such, their presence is an indicator of wastewater (fecal) contamination and potential for the presence of other disease-causing organisms. *Escherichia coli*, or *E. coli*, is a single species of fecal coliforms that is only found in waste from humans and other warm-blooded animals. For drinking water, total coliforms are the standard test because their presence indicates contamination of a water supply by any outside source. For recreational waters, the US Environmental Protection Agency (EPA) recommends using *E. coli* as the best indicator of health risk in water. In the past, tests were done to compare the relative abundance of fecal coliforms and fecal streptococci to indicate whether the probable source of contamination was human or animal. This comparison is no longer considered reliable.

Several test kits are available for volunteer use based on similar methods of growing and distinguishing the bacteria. However, proper handling precautions are essential when testing, for coliforms can be dangerous in case pathogenic organisms are present in the water. Every method for testing coliforms has positive and negative attributes. Selection of the most appropriate method depends on turbidity of the water sample; high or low range bacterial density; ability to distinguish total coliforms, fecal coliforms, and *E. coli* colonies; and use of sterile techniques in diluting, filtering, transferring, and auger handling techniques. For this reason, many of the volunteer monitoring programs do not specify a method but suggest carefully following the directions in the selected test kit. A data report must include a description of the testing method and appropriate units for the results (e.g., colonies per 100 ml). When appropriate facilities are not available for the tests or more accurate tests are needed, professionals should conduct the sampling.

Designing a volunteer monitoring program

Selecting the characteristics to be monitored

The success of any project, including a business or watershed project, requires knowledge and the development of capital and infrastructure. Monitoring is like accounting. An audit of a business will include measurements of the amount of stock on hand, business transactions over time, the capability to produce the product, and interactions between employees and customers. An audit of a stream, lake or wetland system includes similar measurements.

Capital represents the products that are available for sale or use and indicates the short-term viability of the system. The forms of “biological capital” that are available for human use and to support natural productivity include species diversity, population size, population structure, and species interactions. Species diversity includes the number of species and different types of species. Population size is the number (abundance) of individuals. Population structure includes an appropriate mix of both sexes for reproduction and of young, reproducing, and older individuals. Species interactions include predator-prey (feeding) and territorial (defending) behavior. Many checklists for monitoring animals or plants in an ecosystem will include measurements of some or all of these aspects of existing organisms in the lake, stream or wetland.

Measuring the existing capital in a business or ecosystem will not provide information on the long-term success of the system without also measuring the infrastructure. Infrastructure in a business or ecosystem includes the support systems that are necessary to continue production. Aspects of “biological infrastructure” include climate, soils, topography, vegetation, shape and size of the water body, seasonal patterns of temperature and rainfall, and connections between land use and water quality. These aspects are often measured with habitat descriptions, which include surrounding land use and testing the chemical and physical characteristics of the water.

Determining an appropriate level of monitoring effort

In most cases, available funding and time will limit the amount and kind of data collected for a project. The project managers must select the most cost-effective aspects and locations that will provide the most information with the least amount of monitoring. Aspects to consider include the history of monitoring in the project area; the location of sampling sites; the timing of samplings relative to seasonal changes, yearly variation, and storm events; and the combination of characteristics to monitor.

The type of project will provide general direction for selecting an appropriate level of monitoring. Monitoring can be used for quickly scanning waters in an area to identify potential problems; periodically assessing changes in water quality; repeating tests to confirm a problem identified at a location; establishing reasonable water quality goals for a project compared to high quality sites in the region; and using a particular combination of tests to diagnose the probable sources of suspected water quality problems. These factors will indicate the timing, location, and tests that will be most effective for monitoring.

A thorough investigation into existing monitoring data in and around the project area will assist with guiding appropriate monitoring efforts. Where possible, sampling should be repeated at locations where existing information is available for determining trends over time. If sampling techniques are known from past research, the use of similar techniques will increase the comparability of the data. Common sources of information include copies of past reports and historical pictures in the public library; aerial photographs and

soil surveys in the County Soil and Water Conservation District (SWCD) office; aerial photographs dating back to the 1930s in the State Archives in Indianapolis; records of rare species in the Heritage Trust Database, Division of Nature Preserves, IDNR; fisheries reports at the office of the IDNR District Fisheries Biologist or nearest State Fish Hatchery; agency reports at IDNR or IDEM; web pages for agencies and universities; and personal accounts of people who have lived in the watershed. Phone calls to request materials or information are more productive if the reason for the information and exact type of information needed is clearly given.

Site selection for monitoring

The scale of a project indicates how large an area will be covered with the sampling. Individual landowners may wish to test water entering and leaving their properties to determine their contributions to water quality changes. County managers or lake associations may conduct similar samplings but at the scale of the incoming and outgoing water at the county or lake levels. A subwatershed managed for improving land use practices may be sampled and compared to a similar regional subwatershed with known high water quality or with similar starting water quality and no project to assess the effects of the land use project. Water quality could be tested upstream and downstream of a particular project site before and after livestock fencing, manure pit installation, bank stabilization or other site-specific projects.

Site selection depends on location relative to the source, accessibility, and funding. For convenient and permanent access, most sites are located just upstream of a bridge crossing or other access point. Permission for access from private property owners is essential. The sites must be readily identified using a permanent structure (e.g., a road crossing) and latitude/longitude if possible, so future samples can be repeated at exactly the same location. In most watershed projects, sample sites are selected starting with the outlet of the watershed and moving upstream to distinguish inputs of each subwatershed with interest to the project. Testing at mainstem sites below each tributary distinguishes subwatershed effects, if the primary interest is in the mainstem water quality. Sites just upstream of the mouth in each tributary (beyond any backwater effects from the mainstem flow) detect differences in the water quality in each tributary. How finely the watershed is subdivided depends on the project goals and available resources for monitoring.

Timing of monitoring

Decisions about the timing of monitoring are guided by the type and accuracy of information needed for the project. More samples spaced appropriately in time will always improve the accuracy of the information. However, the need for extremely accurate information may be less relevant to decisions regarding most land-use practices. For instance, whether the nitrate level is 15 mg/l or 20 mg/l is not as important as knowing that the water quality standard of 10 mg/l is exceeded most of the year while livestock and animals are using the water as a drinking source. In general, sampling in late summer or fall is most valuable to identify problems related to point-source pollution. At this time of year, water temperatures are high, which decreases oxygen and increases the toxicity of many chemicals, and water levels are low, which concentrates pollution instead of diluting it. Sampling in the spring or immediately after a heavy rainfall will be most useful for determining effects of nonpoint-source pollutants contained in runoff. Any time land use changes, sampling could be repeated over a period of months or years to determine subsequent effects on water quality.

Natural variation can complicate the question of whether human actions are causing a problem. In general, at least two years of sampling under the same conditions is needed to determine whether the stream just had a “bad year” because of unusual weather or other natural causes that reduced the size of the

population. Special note of extreme weather during the sampling year is valuable for distinguishing whether water quality changes are due to humans or nature. Physical, chemical, and biological aspects of streams or lakes also differ, depending on where the sample was collected. Notes regarding the surrounding conditions at the sample site, such as in a pool, under shade trees, or near the bank are also important. Comparisons with similar sites that have not been affected by human activities will adjust for some of the natural variability.

What parameters of water quality can be measured?

Tests are listed below in order from most to least common tests for monitoring:

Habitat	Chemistry	Biology
watershed land use	temperature	aquatic insects
riparian zone	pH	fish
stream bank	dissolved oxygen (DO)	plants/algae
stream channel	phosphate	plankton
physics of flow	Nitrate	Mussels
	turbidity	
	fecal coliform	

What equipment is used?

Equipment cost and complexity differ, depending on which aspects of aquatic ecology are being monitored. The equipment below is listed in order of cost and complexity.

- Data sheets for systematic recording of observations on all aspects.
- Use of photography to document habitat condition or plant and animal observations is strongly recommended.
- Habitat observations can include visual reconnaissance, measuring tapes for depth and width, a variety of flow meters, light meters and other apparatus to determine amount of shading or other physical aspects.
- Kick net, vials, trays, hand lens or microscope for collecting organisms.
- Keys for identifying aquatic insects and other organisms.
- Chemical testing kit or spectrophotometer—county health departments, wastewater treatment plants, or other water utilities may be willing to run some of the more complicated tests (e.g., turbidity, total dissolved solids, fecal coliform, pesticides)
- Computer for data entry and analysis and/or modem to access computerized information (optional).

Data sheets

The appropriate selection of sampling sites and aspects to be measured in combination with accurate and complete records of the results are more important than the use of specific data sheets. Be especially careful to record data with appropriate units of measurement (e.g., inches, meters, mg/l, gallons). Unless the unit of measure is recorded, the number and collecting effort is usually useless. Data sheets are available from several monitoring programs in Indiana. Most of the data sheets are based on similar testing methods, but are arranged slightly differently. To facilitate data entry, record the observations on the sheets that are specific to the program receiving the information. Data sheets are useful as checklists to ensure that all required data have been collected and recorded.

What will it cost?

The cost of monitoring varies, depending on the aspects that are measured and the degree of accuracy. Habitat assessments require less technical training and very little, if any, expensive equipment. Chemical testing can be relatively expensive or very expensive, depending on the accuracy level and types of tests. In general, tests for turbidity, nutrients, and associated physical factors are less costly than tests for pesticides, metals, or other industrial contaminants. Biological monitoring costs about from about the same to somewhat less than chemical testing. In general, testing for macroinvertebrates is less expensive than for fish or mussels, but selection of organism group also depends on the purpose of the monitoring project. Cost for volunteer monitoring test kits can range from \$250 for titration-based tests to \$2500 for automated meters. Funding for projects from many state and federal programs includes a portion set aside for monitoring.